by merely subtracting the weight of the globe when empty from the weight when full. When the globe is empty, its external volume is less than when full, and thus, in order to obtain the true weight, the apparent weight of the gas must be increased by the weight of air whose volume is equal to the change of volume of the globe.

In order to determine the amount of this change of volume, the globe is filled to the neck with recently boiled distilled water, and the effect is observed upon the level in the stem due to a suction of, say, 20 inches of mercury. It is not advisable to carry the exhaustion much further, for fear of approaching too nearly the point at which bubbles of vapour may be formed internally. In the earlier experiments, described in the preliminary note, the upper surface of the liquid was in the stem of the globe itself (below the tap), and the only difficulty lay in the accurate estimation of a change of volume occurring in a wide and somewhat irregular tube. The method employed was to produce, by introduction of a weighed quantity of mercury, a rise of level equal to that caused by the suction.

The advantage of this procedure lay in the avoidance of joints and of the tap itself, but, for the reasons given, the readings were not quite so accurate as might be desired. I wished, therefore, to supplement, if possible, the former determination by one in which the change of volume occurred in a tube narrower and of better shape. With this object in view, the stem of the globe was prolonged by a graduated tubular pipette attached with the aid of india-rubber. The tubes themselves were treated with gutta-percha cement, and brought almost into contact. It had hardly been expected that the joint would prove unyielding under the applied suction, but it was considered that the amount of the yielding could be estimated and allowed for by operations conducted *with tap closed*. The event, however, proved that the yielding at the joint was scarcely, if at all, perceptible.

The pipette, of bore such that 16 cm. corresponded to 1 c.c., was graduated to 0·01, and was read by estimation to 0·001 c.c. In order the better to eliminate the changes due to temperature, readings under atmospheric pressure, and under a suction of 20 inches of mercury, were alternated. On January 28, 1892, a first set gave 0·648 − 0·300 = 0·348 ; a second gave 0·6645 − 0·316 = 0·3485 ; and a third gave 0·675 − 0·326 = 0·349. Similar operations with tap closed[1] gave no visible movement.

The result of the day's experiments was thus 0·3485 for 20 inches, or 0·523 for 30 inches, suction. Similar experiments on January 28, at a different part of the graduation, gave 0·526. On this day the yielding with tap closed was just visible, and was estimated at 0·001. As a mean result, we may adopt 0·524 c.c. The graduation of the pipette was subsequently verified by weighing a thread of mercury that occupied a measured length.

A part of the above-measured volume is due to the expansion of the water when the pressure is relieved. We may take this at 0·000047 of the volume per atmosphere. The volume itself may be derived with sufficient accuracy for the present purpose from the weight of its oxygen contents. It is 2·517/0·00137, or 1837 c.c. The expansion of the water per atmosphere is thus 0·000047 × 1837, or 0·087 c.c. This is to be subtracted from 0·524, and leaves 0·437 c.c. This number applies strictly to the volume inclosed within the glass, but the change in the external volume of the globe will be almost the same.

The correction now under consideration is thus the weight of 0·437 c.c. of air at the average temperature of the balance room. The density of this air may be estimated at 0·00122; so that the weight of 0·437 c.c. is 0·000533 gram. This is the quantity which must be added to the apparent weights of the gases. The former estimate was 0·00056 gram. The finally corrected weights are thus—

$$H = 0·158531, \qquad O = 2·51777 ;$$

and for the ratio of densities we have

15·882.

This corresponds to a mean atmospheric condition of pressure and temperature.

If we combine the above ratio of densities with Prof. Morley's ratio of volumes, viz. 2·0002 : 1, we get, as the ratio of atomic weights, 15·880.

If we refer to the table, we see that the agreement of the first and third series of hydrogen weighings is very good, but that the mean from the second series is decidedly lighter. This may have been in part fortuitous, but it is scarcely probable that it was so altogether. Under the circumstances we can hardly reckon the accuracy of the final results as closer than $\frac{1}{3000}$.

The accompanying table of results, found by various experimenters, may be useful for comparison :—

Name.	Date.	Atomic weights.	Densities.
Dumas	1842	15·96	—
Regnault	1845	—	15·96
Rayleigh	1888	—	15·884
Cooke and Richards ...	1888	15·869	—
Keiser	1888	15·949	—
Rayleigh	1889	15·89	—
Noyes	1890	15·896	—
Dittmar	1890	15·866	—
Morley	1891	15·879	—
Leduc	1891	—	15·905
Rayleigh	1892	—	15·882

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[1] For greater security the tap was turned while the interior was under suction.

THE ORIGIN OF THE YEAR.[1]

II.

Difficulties.

THERE no doubt was a time when the Egyptian astronomer-priests imagined that, by the introduction of the 365-days year, beginning at the solstice or the nearly contemporaneous Nile flood (there is an interval of three days between them in the present Coptic calendar[2]), and by marking the commencement, in addition, by the heliacal rising of one of the host of heaven, they had achieved finality. But alas ! the dream must soon have vanished.

Even with this period of 365 days, the true length of the year had not been reached ; and soon, whether by observations of the beginning of the inundation, or by observations of the solstice in some of the solar temples which, beyond all doubt, were then in existence, it was found that there was a difference of a day every four years between the beginning of the natural and of the newly-established year, arising, of course, from the fact that the true year is 365 days *and a quarter of a day* (roughly) in length.

The true year and this established year of 365 days, then, behaved to each other as follows. Let us take a year when the solstice, representing the beginning of the

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[1] Continued from vol. xlv. p. 490.

[2] The calendar in question (given both by Brugsch and De Rougé) is, doubtless, a survival from old Egyptian times It is good for the neighbourhood of Cairo, and the relation of the important days of the inundation to the solstice, in that part of the river, is as follows :—

Night of the drop	11 Payni	
	15 „ ...	Summer solstice.
Beginning of the inundation ...	18 „ ...	3 days after.
Assembly at the Nilometer ...	25 „ ...	10 „
Proclamation of the inundation ...	26 „ ...	11 „
Marriage of the Nile	18 Mesori ...	63 „
The Nile ceases to rise...	16 Thoth ...	96 „
Opening of the dams	17 „ ...	97 „
End of the greater inundation ...	7 Phaophi ...	117 „

true year, occurred on the 1st Thoth of the established year. We should have, in the subsequent years, the state of things described in the diagram. The solstice would year by year occur *later* in relation to the 1st of Thoth. The 1st of Thoth would occur *earlier*, in relation to the solstice; so that in relation to the established year the solstice would sweep forwards among the days; in relation to the true year the 1st of Thoth would sweep backwards.

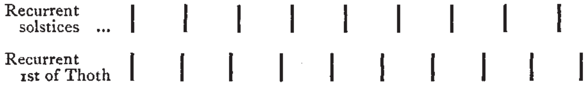

Fig. 2.—Showing the relation between the recurrences of the solstices and the 1st of Thoth.

Let us call the true natural year a *fixed* year: it is obvious that, the months of the 365-day year would be perpetually varying their place in relation to those of the fixed year. Let us, therefore, call the 365-day year a *vague* year.

Now if the fixed year were exactly $365\frac{1}{4}$ days long, it is quite clear that, still to consider the above diagram, the 1st of Thoth would again coincide with the solstice in 1460 years, since in 4 years the solstice would fall on the 2nd of Thoth, in 8 years on the 3rd of Thoth, and so on ($365 \times 4 = 1460$).

But the fixed year is not $365\frac{1}{4}$ days long *exactly*. In the time of Hipparchus 365·25 did not really represent the true length of the solar year; instead of 365·25 we must write 365·242392—that is to say, the real length of the year is a little *less* than $365\frac{1}{4}$ days.

Now the length of the year being a little *less*, of course we should only get a second coincidence of the 1st of Thoth vague with the solstice in a *longer* period than the 1460-years cycle; and, as a matter of fact, 1506 years are required to fit the months into the years with this slightly shortened length of the year. In the case of the solstice and the vague year, then, we have a cycle of 1506 years.

The variations between the fixed and vague years were known perhaps for many centuries to the priests alone. They would not allow the established year of 365 days, since called the *vague* year, to be altered; and so strongly did they feel on this point that, as already stated, every king had to swear when he was crowned that he would not alter the year. We can surmise why this was. It gave great power to the priests; they alone could tell on what particular day of what particular month the Nile would rise in each year, because they alone knew in what part of the cycle they were; and in order to get that knowledge they had simply to continue going every year into their Holy of Holies one day in the year as the priests did afterwards in Jerusalem, and watch the little patch of bright sunlight coming into the sanctuary. That would tell them exactly the relation of the true solar solstice to their year; and the exact date of the inundation of the Nile could be predicted by those who could determine observationally the solstice, but by no others.

But now suppose that instead of the solstice we take the heliacal rising of Sirius, and compare the successive risings at the solstice with the 1st of Thoth.

But why, it will be asked, should there be any difference in the length of the cycles depending upon successive coincidences of the 1st of Thoth with the solstice and the heliacal rising of Sirius? The reason is that stars change their places, and the star to which they trusted to warn them of the beginning of a new year was, like all stars, subject to the effects brought about by the precession of the equinoxes. Not for long could it continue to rise heliacally either at the solstice or the Nile flood.

Among the most important contributors to the astronomical side of this subject are M. Biot and Prof. Oppolzer. It is of the highest importance to bring together the fundamental points which have been made out by their calculations. We have determinate references to the heliacal rising of Sirius, to the 1st of Thoth, to the solstice, and to the rising of the Nile in connection with the Egyptian year; but, so far as I have been able to make out, we find nowhere at present any sharp reference to the importance of their correlation with the times of the *tropical* year at which these various phenomena took place. The question has been complicated by the use by chronologists of the Julian year in such calculations; so the Julian year and the use made of it by chronologists have to be borne in mind. Unfortunately, many side issues have in this way been raised.

The heliacal rising of Sirius, of course—if in those days a true *tropical* year was being dealt with—would have given us a more or less constant variation in the time of the rising over a long period, *on account of its precessional movement;* but M. Biot and others before him have pointed out that the variation in the time of the year at which the heliacal rising took place, produced by that movement, was almost exactly equal to the error of the *Julian* year as compared with the true tropical or Gregorian one. Biot showed by his calculations, using the solar tables extant before those of Leverrier, that from 3200 B.C. to 200 B.C. in the Julian year of the chronologists, Sirius had constantly, in each year, risen heliacally on July 20 Julian = June 20 Gregorian. Oppolzer, more recently, using Leverrier's tables, has made a very slight correction to this, which, however, is practically immaterial for the purposes of a general statement. He shows that in the latitude of Memphis, in 1600 B.C., the heliacal rising took place on July 18·6, while in the year 0 it took place on July 19·7, both Julian dates.

The variation from the true tropical year brought about by the precessional movement of Sirius or any other star, however, can be watched by noting its heliacal rising in relation to any physical phenomenon which marks the true length of the tropical year. Such a phenomenon we have in the rising of the Nile, which, during the whole course of historical time, has been found to rise and fall with absolute constancy in each year, the initial rise of the waters, some little way above Memphis, taking place very nearly at the summer solstice.

Again, M. Biot has made a series of calculations from which we learn that the heliacal rising of Sirius AT THE SOLSTICE occurred on July 20 (Julian) in the year 3285 B.C., and that in the year 275 B.C. the *solstice* occurred on June 27 (Julian), while the heliacal *rising of Sirius* took place, as before, on July 20 (Julian), so that in Ptolemaic times, at Memphis, there was a difference of time of about 24 days between the heliacal rising of Sirius and the solstice, and therefore the beginning of the Nile flood in that part of the river. This, among other things, is shown in Fig. 3.

We learn from the work of Biot and Oppolzer then that the precessional movement of the star caused successive heliacal risings of Sirius at the solstice to be separated by almost exactly $365\frac{1}{4}$ days—that is, by a greater period than the length of the true year. So that, in relation to this star, two successive heliacal risings at the 1st of Thoth vague are represented by a period of ($365\frac{1}{4} \times 4 =$) 1461 years, while in the case of the solstices we want 1506.

Now in books on Egyptology the period of 1461 years is termed the Sothic period, and truly so, as it very nearly correctly measures the period elapsing between two heliacal risings at the solstice (or the beginning of the Nile flood) on the 1st of Thoth in the *vague* year.

But it is merely the result of *chance* that $365\frac{1}{4} \times 4$ represents it. It has been stated that this period had not any ancient existence, but was calculated back in later times. This seems to me very improbable. I look upon it rather as a true result of observation, the more so as the period was shortened *in later times*, as Oppolzer has shown.

It will be seen that our investigations land us in several astronomical questions of the greatest interest, and that the study is one in which modern computations, with the great accuracy which the work of Leverrier and others give to them, can come to the rescue, and eke out the scantiness of the ancient records.

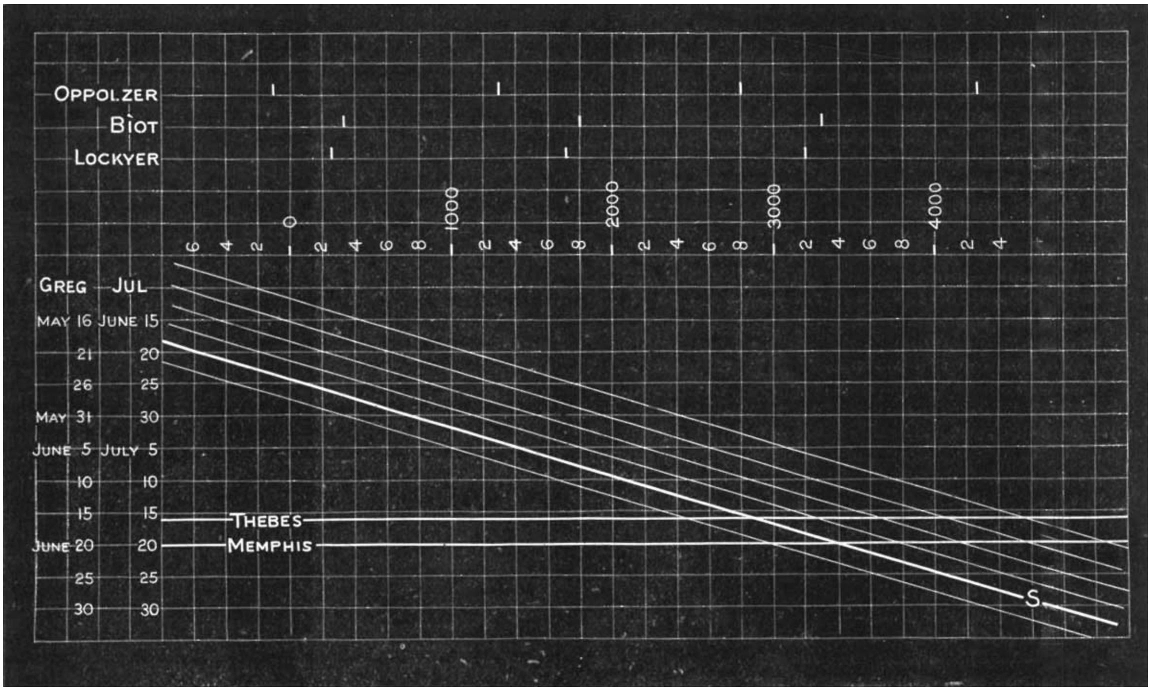

Fig. 3.—The conditions of the heliacal rising of Sirius from 4000 B.C. to 600 A.D. The diagram shows (1) by white horizontal lines, the Gregorian and Julian dates for the rising at Thebes and at Memphis. (2) By the full diagonal line the *Julian* date of the solstice or beginning of the inundation in each century, at a point of the river near Memphis. The fainter lines show the Julian dates for other places where the time of the beginning of the flood differs by three days from the Memphis dates. The interval between each line represents a difference of three days in the arrival of the flood (3) The interval in days between the heliacal rising and the inundation at different periods and at different points on the river. This can be determined for each century by noticing the interval between the proper diagonal line and that indicating the heliacal rising. (4) By dots at the top of the diagram the commencement of the Sothic period as determined by Oppolzer, Biot, and the author.

To consider the subject further, we must pass from the mere question of the year to that of chronology generally, but in doing so I shall limit myself to the more purely astronomical part. To go over the already vast literature is far from my intention, nor is it necessary to attempt to settle all the differences of opinion which exist, and which are so ably referred to by Krall in his masterly analysis, to which I own myself deeply indebted. The tremendously involved state of the problem may be gathered from the fact that the authorities are not yet decided whether many of the dates really belong to a fixed or a vague year!

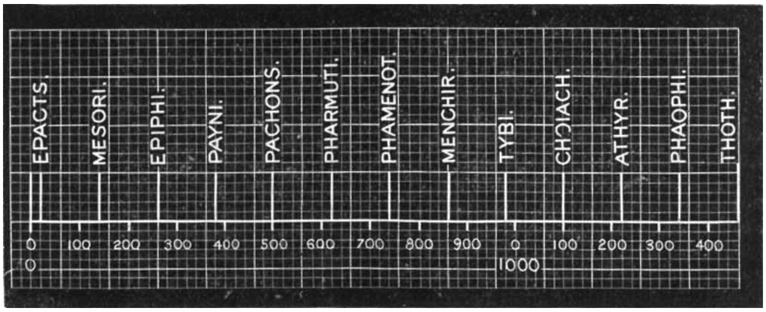

Fig. 4.—The distribution of the 1st of Thoth (representing the rising of Sirius) among the Egyptian months in the 1460-year Sothic cycle.

Let us, rather, put ourselves in the place of the old Egyptians, and inquire how, out of the materials they had at hand, a calendar could be constructed in the simplest way.

To make what follows clearer, it will be well to construct another diagram somewhat like the former one.

Let us map out the 1460 years which elapsed between two successive coincidences between the 1st of Thoth in the vague year and the heliacal rising of Sirius at the solstice, so that we can see at a glance the actual number of years from any start point (= 0) at which the 1st of Thoth in the vague year occurred successively further and further from the heliacal rising, until at length, after a period of 1460 years, it coincided again.

As the Sirius-year is longer than the vague one, the first vague year will be completed before the first Sirius-year, hence the second vague year will commence just before the end of the fixed year, and that is the reason that I have reversed the order of months in the diagram (Fig. 4).

Now it is clear that, if the Egyptians really worked in this fashion, any special day in the vague year given as the date of the heliacal rising of Sirius would enable us to determine the number of years which had elapsed from the beginning of the cycle. This will help us to determine whether or not they acted on this principle, or used one widely different. In such an investigation as this, however, we are terribly hampered by the uncertainty of Egyptian dates; while, as I have said before, there is great divergence of opinion among Egyptologists as to whether, from very early times, there was not a true fixed year.

But let us suppose that the vague year was in use, and that the rising of Sirius started the year; then, if we can get any accepted date to work with, and use the diagram to see how many years had elapsed between that date and the start-point of the cycle, we shall see if there be any cyclical relation, and if we find it, it will be evidence, so far as it goes, of the existence of a vague year.

Now it so happens that there are three references, with dates given, to the rising of Sirius in widely different times; and, curiously enough, the month references are nearly the same. I begin with the most recent, as in this case the date can be fixed with the greater certainty. It is an inscription at Philæ, described by Brugsch (p. 87), who states that, when it was written, the 1st of Thoth = 28th of Epiphi. That is, according to the view we are considering, the heliacal rising of Sirius occurred on the 28th of Epiphi in the vague year. He fixes the date of the inscription between 127 and 117 B.C. Let us take it as 122. Next, referring to our diagram to find how many years had elapsed since the beginning of the cycle, we have—

Days.
5 Epacts.
30 Mesori.
2 Epiphi.
—
37 × 4 = 148 years elapsed.

The cycle, then, began in (148 + 122 =) 270 B.C.

We next find a much more ancient inscription recording the rising of Sirius on the 28th of Epiphi. Obviously, if the Sothic cycle had anything to do with the matter, this must have happened 1458 years earlier, *i.e.* about (1458 + 122 =) 1580 B.C. Under which king? Thotmes III., who reigned, according to Lepsius, 1603–1565 B.C.; according to Brugsch, 1625–1577. Now, the inscription in question is stated to have been inscribed by Thotmes III., and, it may be added, on the temple (now destroyed) at Elephantiné.

There is yet another inscription, also known to be of a still earlier period, referring to the rising of Sirius on the 27th of Epiphi. We may neglect the difference of one day; and again, if the use of the Sothic cycle were the origin of the identity of dates, we have this time, according to Oppolzer, a period of 1460 years to add: this gives us (1584 + 1460 =) 3044 B.C. Again under which king? Here we are face to face with one of the difficulties of these inquiries. It may be stated, however, that the inscription is ascribed to Pepi, and that, according to various authorities, he reigned some time between 3000 and 3700 B.C.

We come, then, to this: that one of the oldest dated inscriptions known seems to belong to a system which continued in use at Philæ up to about 100 B.C., and it was essentially a system of a vague year.

Now, assuming that the approximate date of the earliest inscription is 3044 B.C., and that it represented the heliacal rising of Sirius on the 27th of Epiphi; the year 3044 must have been the [(5 + 30 + 3) × 4 =] 152nd after the beginning of the cycle. The cycle, then, must have commenced (3044 + 152 =) 3196 B.C.

According to Biot's calculation, the first heliacal rising of Sirius at the solstice took place in the year 3285 B.C.,

If we assume that the real date of Pepi, who, it is stated, reigned 100 years, included the year 3044 B.C., it may be that the inscriptions to which I have directed attention give us three Sothic cycles beginning—

122 + 148 = 270 B.C.
1580 + 148 = 1728 B.C.
3044 + 148 = 3192 B.C.

J. NORMAN LOCKYER.

(*To be continued.*)

NOTES.

THE list of those on whom honorary degrees are to be conferred at Cambridge on the occasion of the installation of the Duke of Devonshire as Chancellor shows that culture, and especially scientific culture, goes for very little among the classes of distinction recognized by the University. Eminence in the political world and in society seems to be the claim chiefly recognized.

SCIENCE was well represented at the annual dinner of the Incorporated Society of Authors on Tuesday. The chair was occupied by Prof. Michael Foster, and Sir Archibald Geikie was one of those who responded to the toast of "Literature."

DR. A. F. BATALIN has been appointed Director of the Imperial Botanic Garden at St. Petersburg, in succession to the late Dr. E. Regel.

THE ninety-seventh meeting of the Yorkshire Naturalists' Union will be held on Whit Monday, June 6. Some interesting notes on the physical geography and geology, botany, entomology, conchology, and vertebrate zoology of the district have been issued for the benefit of those who intend to be present. We are glad to see that members are expected to "do all in their power to discourage the uprooting of ferns and rare plants, or the too free collection of rarities of any kind."

THE Botanical Society of France has held its annual meeting at Algiers, commencing April 16, under the presidency of the Algerian botanist, M. Battandier. In addition to the reading of papers, excursions were made to Biskra, and other spots on the border of the Sahara.

WE have received the programme of the ninth International Congress of Orientalists. It is to be held in London from September 5 to 12, Prof. Max Müller acting as President. The Duke of Connaught has accepted the office of Honorary President. The following are the Vice-Presidents: the Marquis of Ripon, Lord Northbrook, Lord Reay, Major-Gen. Sir Henry Rawlinson, the Rt. Hon. Sir M. E. Grant Duff, Sir John Lubbock, Sir William Muir, Sir William W. Hunter, Sir George Birdwood, Sir William Markby, Sir Edwin Arnold, the Provost of Oriel College, Oxford, the Master of Balliol College, Oxford, the Master of Christ's College, Cambridge, H. S. King, and M. M. Bhownuggree. The Treasurer is Mr. E. Delmar Morgan. The Honorary Secretaries are: the Rev. C. D. Ginsburg, D.D., Prof. T. W. Rhys Davids, the Rev. E. W. Bullinger, D.D., Prof. A. A. Macdonell, M. M. Bhownuggree, the Raja Peari Mohan Mukharji (for Bengal), Prof. Peterson (for Bombay). Many eminent foreign scholars and members of former Congresses have signified their adhesion, and several important Societies have undertaken to send delegates. The sections into which the work of the Con-